RELATED APPLICATION

This application is a Continuation-in-Part of United States patent application entitled "IMPROVED GOLF CLUB FACE FLEXURE CONTROL SYSTEM", U.S. Serial No. 09/614,107, Filed: July 12, 2000, which is a Continuation-in-Part of United States patent application entitled "GOLF CLUB FACE FLEXURE CONTROL SYSTEM", U.S. Serial No. 09/344,172, Filed: June 24, 1999.

BACKGROUND OF THE INVENTION

The primary objective of the present invention is to design golf clubs for a variety of golfers that optimizes the distance the golfer impels the golf ball. To do this from a physics standpoint, it is necessary to obtain a maxi-mum deflection of the ball striking face, or something ap-proaching that maximum, during the collision with the ball while at the same time maintaining the other parameters of the golf club head within acceptable limits.

This spring-like effect of the ball striking face, which is necessary to achieve maximum distance, has been widely misunderstood in the golf industry, even by many golf club designers. Many golf club designers believe that any deflection of the golf club face during impact with its resulting spring-like effect on the golf ball is a design in

violation of the Rules of the USGA. This is a myth because virtually all of the thin walled hollow metal wood clubs have significant face deflection during impact and in fact impart a spring-like effect to the ball as it exits the face. This deflection can be as high as in the range of 0.100 inches. And the USGA has approved such clubs although prior to 1999, it did no ball speed or rebound testing on golf clubs. The USGA has now adopted, although in a state of transition, a ball impact club head test in which the rebound speed of the golf ball is measured and compared against the inbound speed of the ball impacting the club head sample in a stationary position. If the rebound speed of the ball exceeds a certain percentage of the inbound speed, the club will fail the test and the USGA will notify the submitter that the club head has failed the ball speed test and will not be approved by the USGA.

While it is the primary object of the present invention to maximize the face deflection, without causing face failure, and thus maximize face wall energy imparted to the ball, this does not necessarily mean that club heads made in accordance with the present invention will fail the USGA testing, and club heads designed in accordance with the present invention should be submitted to the USGA for such testing and this application makes no representation as to

whether such clubs will or will not pass the USGA testing, particularly bearing in mind that the testing procedures and parameters are presently in a state of flux.

Investment casting techniques innovated in the late 1960s have revolutionized the design, construction and performance of golf club heads up to the present time. Initially only novelty putters and irons were investment cast, and it was only until the early years of the 1980s that investment cast metal woods achieved any degree of commercial success. The initial iron club heads that were investment cast in the very late 1960s and early 1970s innovated the cavity backed club heads made possible by investment casting which enabled the molder and tool designer to form rather severe surface changes in the tooling that were not possible in prior manufacturing techniques for irons which were predominantly at that time forgings. The forging technology was expensive because of the repetition of forging impacts and the necessity for progressive tooling that rendered the forging process considerably more expensive than the investment casting process and that distinction is true today although there have been recent techniques in forging technology to increase the severity of surface contours albeit them at considerable expense.

The investment casting process, sometimes known as the lost wax process, permits the casting of complex shapes found beneficial in golf club technology, because the ceramic material of the mold is formed by dipping a wax master impression repeatedly into a ceramic slurry with drying periods in-between and with a silica coating that permits undercutting and abrupt surface changes almost without limitation since the wax is melted from the interior of the ceramic mold after complete hardening.

This process was adopted in the 1980s to manufacture "wooden" club heads and was found particularly successful because the construction of these heads requires interior undercuts and thin walls because of their stainless steel construction. The metal wood club head, in order to conform to commonly acceptable club head weights on the order of 195 to 210 gms. when constructed of stainless steel, must have extremely thin wall thicknesses on the order of .020 to 0.070 inches on the perimeter walls to a maximum of 0.125 inches on the forward wall which is the ball striking surface. This ball striking surface, even utilizing a high strength stainless steel such as 17-4, without reinforcement, must have a thickness of at least .125 inches to maintain its structural integrity for the high club head speed player of today who not uncommonly has speeds in the range of 100 to 150 feet per second at ball impact.

Faced with this dilemma of manufacturing a club head of adequate strength while limiting the weight of the club head in a driving metal wood in the range of 195 to 210 gms., designers have found it difficult to increase the perimeter weighting effect of the club head.

In an iron club, perimeter weighting is an easier task because for a given swing weight, iron club heads can be considerably heavier than metal woods because the iron shafts are shorter. So attempts to increase perimeter weighting over the past decade have been more successful in irons than "wooden" club heads. Since the innovation of investment casting in iron technology in the late 1960s, this technique has been utilized to increase the perimeter weighting of the club head or more particularly a redistribution of the weight of the head itself away from the hitting area to the perimeter around the hitting area, usually by providing a perimeter wall extending rearwardly from the face that results in a rear cavity behind the ball striking area. Such a club head configuration has been found over the last two plus decades to enable the average golfer, as well as the professional, to realize a more forgiving hitting area and by that we mean that somewhat off-center hits from the geometric center of the face of the club results in shots substantially the same as those hits on the center of the club. Today it is not uncommon to find

a majority of professional golfers playing in any tournament with investment cast perimeter weighted irons confirming the validity of this perimeter weighting technology.

Metal woods by definition are perimeter weighted because in order to achieve the weight limitation of the club head described above with stainless steel materials, it is necessary to construct the walls of the club head very thin which necessarily produces a shell-type construction where the rearwardly extending wall extends from the perimeter of the forward ball striking wall, and this results in an inherently perimeter weighted club, not by design but by a logical requirement.

Prior attempts to manufacture very large stainless steel metal club heads with larger than normal faces has proved exceedingly difficult because of the 195 to 210 gm. weight requirements for driving club heads to achieve the most desirable club swing weights. Thus, to the present date stainless steel "jumbo" club heads have been manufactured with standard sized face walls, deeply descending top walls from the front to the rear of the club head, and angular faceted sole plates all designed to decrease the gross enclosed volume of the head but which do not detract from the apparent, not actual, volumetric size of the head. This

has led to many manufacturers switching from stainless steel to aluminum and titanium alloys, which are of course lighter, to enlarge the head as well as the face.

A further problem in the prior art references which suggest utilizing these rigidifying elements, is that they are completely silent on how these reinforcing elements, when not cast into the face wall, are attached into the club head. And the method of attachment, as will be seen from the present invention, is critical to the benefits of increasing resonant frequency and rebound of the face wall in accordance with the present invention. Presently known bonding techniques are not sufficient to yield these benefits.

Still another of these prior references suggests making the head of synthetic material and the support rod of a similar material, but these low modulus and soft materials cannot significantly raise the resonant frequency or rebound time of the ball striking face wall.

The following patents or specifications disclose club heads containing face reinforcing elements:

FOREIGN PATENTS:

British Patent Specification, No. 398,643, to Squire, issued 9-21-33;

UNITED STATES PATENTS:

Clark, No. 769,939, issued 9-13-04
Palmer, No. 1,167,106, issued 1-4-16
Barnes, No. 1,546,612, issued 7-21-25
Drevitson, No. 1,678,637, issued 7-31-28
Weiskoff, No. 1,907,134, issued 5-2-33
Schaffer, No. 2,460,435, issued 2-1-49
Chancellor, No. 3,589,731, issued 6-29-71
Glover, No. 3,692,306, issued 9-19-72
Zebelean, No. 4,214,754, issued 7-29-80
Yamada, No. 4,535,990, issued 8-20-85
Chen, et al., No. 4,681,321, issued 7-21-87
Kobayashi, No. 4,732,389, issued 3-22-88
Shearer, No. 4,944,515, issued 7-31-90
Shiotani, et al., No. 4,988,104, issued 1-29-91
Duclos, No. 5,176,383, issued 1-5-93
Atkins, No. 5,464,211, issued 11-7-95
Rigal, et al., No. 5,547,427, issued 8-20-96
Lu, No. Re. 35,955

The Lu, U.S. Patent No. Re. 35,955, shows a secondary wall that reinforces the forward wall, but the structure is too heavy and complex, and the resulting club would be overweight and not properly balanced.

In my parent application, U.S. Serial No. 09/344,172, Filed: 6-24-99, I disclose a piston that is spaced from the rear of the face wall that impacts the face wall near its maximum deflection point.

It is a primary object of the present invention to reduce face modulus to provide maximum face flexure.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, a high impact golf club head with a face wall surrounded by a perimeter wall is provided. Upon ball impact this face wall impacts a separate light weight open cellular structure that supports the face wall as it deflects and minimizes face wall failure.

Toward these ends, the unit cellular structure is generally planar and has the same general outer shape as the face wall, and it is attached either to the face wall or the perimeter wall at its periphery. The cellular structure includes a plurality of ribs intersected and integral with a second plurality of ribs. In the embodiment shown in the drawings, the two sets of ribs are orthogonally related but they need not be. They could be formed in other patterns such as triangles or hexagonal cells.

An important aspect of the cellular structure is that it is comprised of "T" shaped ribs and the space between the ribs is open providing a very light weight structure to minimize total face weight. The vertical bar of the "T" faces the rear surface of the face wall and the end of the vertical bar is impacted by the rear surface of the face wall at impact. This dynamic engagement of the face wall and the "T" beam ribs transforms the composite of the face

wall and the ribs into an "I" beam which is well known to be far stronger in its resistance to bending movements than a "T" beam.

The unit cellular structure can be positioned either in continuous engagement with the rear surface of the face wall or spaced slightly behind it, on the order of 0.030 to 0.100 inches depending upon the deflection characteristics of the face wall determined by its wall thickness, material selection and hardness. When in continuous engagement with the rear surface of the face wall the unit cellular structure restricts face wall deflection far less than if the ribs were formed or cast integrally with the face wall. In this regard it should be noted that the "T" shaped configuration of the ribs would also prohibit them from being formed with the face wall because of the myriad of undercuts created between the "T" and the rear of the face wall.

Also, the forward surface of the cellular network can be slightly spaced from the rear surface of the face wall. This enables the face wall to deflect unrestricted during a first portion of its travel, and be restricted by the cellular network in a second portion of travel under ball impact. This restriction is described in detail in the parent application and incorporated herein by reference.

In my parent application, U.S. Serial No. 09/614,107, Filed: 7-12-00, a secondary wall behind the face wall that significantly raises the ball striking face wall modulus of elasticity. By raising the face wall modulus as the face deflects, the elastic limit of the face is never exceeded even if the club head is swung at a significantly higher speed than the maximum design speed. This significant increase in face wall modulus also increases the energy transferred to the ball and ball exit velocity.

An object of this parent invention is to maximize the spring effect the club head imparts to the golf ball to maximize energy transfer to the ball and ball distance. To do this, the face wall is thinned to the point of near failure in each of the speed ranges and hardened by heat treatment, forging, or rolling. Face material is selected to achieve maximum hardness to enhance its spring effect. The beta titanium alloys can achieve high Rockwell or Vickers hardness when properly heat treated, and can be used to achieve the benefits of the present invention, but other alloys of other metals such as steel may be used, as well as other titanium alloys such as 6A14V. One beta titanium alloy that has been found particularly beneficial is Ti-15Mo-5Zr-3Al(Aluminum) ST 735 degrees C, Aged 500 degrees C, a

solution treated alloy having a high tensile strength 213 kpsi, a high hardness of Vickers 412, a modulus of elasticity of 14,500 ksi, and an elongation to break of 14%.

A secondary wall is positioned parallel to and just behind the face wall. As the face wall deflects, at a sufficient club head speed, it will impact the secondary wall, thereby raising the effective modulus of the face wall and prevent the face wall from failing. The secondary wall is a light weight open cellular structure.

The secondary wall is designed and positioned to be impacted by the face wall at about 80% of the proportional limit of the face wall. The proportional limit is the force applied to the face wall where permanent deformation occurs. 80% is selected because face failure can occur before the proportional limit as a result of other causes such as cyclical stress failure or fatigue failure. It should be understood that values above and below 80% are within the scope of the present invention.

It should also be understood that the values for face thickness given in this application; namely, 0.050 to .120 inches and the values for secondary wall spacing; i.e., 105 to 0.040 inches are values for one specific alloy with a specific heat treatment.

With alloy selection and heat treatment, these values will vary in practice and are within the scope of this invention. Since thinner faces offer greater opportunity for greater face deflection, face thickness in the future may be below the above values and secondary wall spacing may be above the above values without departing from the principles of the present invention.

The face wall can also be formed of a different alloy than the club head. For example, the club head may be cast from 6AIV4 titanium, and the face may be cast or forged using the above Ti-15Mo-5Zr-3Al ST 735 degrees C, Aged 500 degrees C.

To understand the design philosophy of the present invention, it is helpful to understand exactly how the club head is designed. Firstly, a fairly large number, approximately 20, of club heads are compression tested, each with a different face modulus of elasticity. Each of these faces is deflected to its elastic limit, and the face deflection at that elastic limit is recorded. This testing is done without the secondary wall in position. After these results are tabulated, the face walls are installed in these club heads with the secondary walls spaced from the bottom of the face wall sockets a distance so that the face wall impacts the piston at a force approximately 80% to 85% of the force recorded at the proportional limit for that club

head. However, something greater than 85% may also be appropriate after fatigue testing analysis is completed for the particular club head design in question, and such is within the scope of the present invention.

The inherent result of this design process is to have a minimum face thickness reducing club head weight so the additional weight of the secondary wall does not result in overweight club heads. Also, because this design reduces face weight, the saved weight can be moved to the perimeter walls for improved perimeter weighting.

While the impact of the secondary wall with the front face may impart additional energy to the ball during impact, its primary function is to permit the club face within a substantial portion of each speed range to flex to its maximum value without exceeding the proportional or elastic limit of the face wall. And face failure is a significant problem in the design of metal wood clubs. This applicant has been designing golf clubs using long driving competition, LDA, for many years, and has knowledge that many of the very well known driver clubs fail as often as once a week for these high swing speed players, in excess of 120 mph, and this phenomenon is not known or experienced by the low swing speed player. The philosophy of the present invention is to permit the slow swing speed player, as well

as the high swing player, to press the elastic limit of his club face to maximize club head and face wall energy transfer to the ball.

Other objects and advantages will appear more clearly from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a front view of a club head according to the present invention;

Fig. 2 is a top view of the club head illustrated in Fig. 1;

Fig. 3 is an exploded perspective of the club head illustrated in Figs. 1 and 2;

Fig. 4 is a bottom view of the club head illustrated in Figs. 1 to 3;

Fig. 5 is a cross-section from the rear looking toward the front of the club head taken generally along line 5-5 of Fig. 4;

Fig. 6 is a longitudinal section taken through the club head geometric center generally along line 6-6 of Fig. 5;

Fig. 7 is a fragmentary longitudinal generally horizontal section taken centrally through the club generally along line 7-7 of Fig. 1;

Fig. 8 is a fragmentary longitudinal section generally similar to Fig. 7 upon ball impact;

Fig. 9 is a front view of another club head according to the present invention;

Fig. 10 is a top view of the club head illustrated in Fig. 9;

Fig. 11 is a bottom view of the club head illustrated in Figs. 9 and 10;

Fig. 12 is a cross section of the rear of the secondary wall taken generally along line 4-4 of Fig. 11;

Fig. 13 is a horizontal section through the club head illustrated in Figs. 9 to 12 illustrating the face wall and the secondary wall;

Fig. 14 is a cross section similar to Fig. 13 with the club head impacting a golf ball and the face wall engaging the secondary wall;

Figs. 15 to 18 are cross sections of four ball striking face walls according to the present invention with exemplary secondary wall spacings;

Fig. 19 is a vertical section taken generally along line 11-11 of Fig. 13;

Fig. 20 is a horizontal section similar to Fig. 13 with the Fig. 15 face wall installed therein;

Fig. 21 is a vertical section taken generally along line 13-13 of Fig. 20;

Figs. 22 to 24 illustrate the club head with the Figs. 16 to 18 face walls installed therein, but unfinished;

Fig. 25 is a bottom heel perspective of another club head made in accordance with the parent application;

Fig. 26 is a bottom toe perspective of the club head illustrated in Fig. 25;

Fig. 27 is an enlarged front view of the club head illustrated in Figs. 25 and 26;

Fig. 28 is a top view of the club head illustrated in Figs. 25 to 27;

Fig. 29 is a right side view taken from the heel of the club head illustrated in Figs. 25 to 28;

Fig. 30 is a left side toe view of the club head illustrated in Fig. 29;

Fig. 31 is a bottom view of the club head illustrated in Figs. 25 to 30;

Fig. 32 is a longitudinal section of the club head illustrated in Figs. 25 to 31 taken off the center line thereof so that the power piston does not appear therein;

Fig. 33 is a cross section of the club head illustrating the rear of the front face and the front face socket;

Fig. 34 is a cross section of the club head looking rearwardly from the Fig. 33 section showing the power piston extending forwardly therefrom;

Figs. 35 to 38 are similar cross sections illustrating the differing face thicknesses and face modula in the four club heads in the line of club heads;

Fig. 39 is a cross section similar to Figs. 33 to 37 at ball impact with the face wall being pressed and the face wall impacting the front face at the piston, and;

Fig. 40 is a stress strain curve for each of the club heads illustrated in Figs. 35 to 38.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, it should be understood that Figs. 1 to 8 relate to the new subject matter in the present application and that Figs. 9 to 40 correspond to Figs. 1 to 32 in parent application, U.S. Serial No. 09/614,107, Filed: 7-12-00, which includes all Figures from U.S. Serial No. 09/344,172, Filed: 6-24-99.

Referring to the drawings, it should be understood that Figs. 1 to 8 relate to the new subject matter of the present application, and that Figs. 9 to 40 correspond respectively to Figs. 1 to 16 in parent application, U.S. Serial No. 09/614,107, Filed: 7-12-00; and Figs. 17 to 32 in 09/344,172, Filed: 6-24-99.

Referring initially to Fig. 1 to 8, a club head 10 is illustrated according to the present invention and includes a body 11 and interchangeable face walls 12. The body 11 may be formed in forward and rear pieces as described in my U.S. Patent No. 5,888,148.

The body 11 includes an upper crown wall 13, a toe wall 14, a heel wall 15, and a sole plate 17. An external portion 19 of the hosel assembly 20 shown in Fig. 5, projects upwardly from the crown wall 11.

The hosel assembly 20 includes an upper portion 21 and a spaced lower portion 22.

The crown wall 13, the toe wall 14, the heel wall 15, and the sole plate 17 together form the perimeter wall that surrounds the ball striking face wall 12.

As seen in Figs. 1, and 6, 7, and 8, a thin, low friction film 40 is bonded to the rear surface of the face plate 12, and those two elements together sandwich a secondary open cellular wall 42 in open front 43 to the body 11. A plurality of integral tabs 45 in the body engage the rear surface of the secondary wall 42 and locate it within the body.

As seen in Fig. 7 and others, the forward surface of the wall 42 is spaced rearwardly from the rear surface 48 of the film 40 a short distance so that upon ball impact illustrated in Fig. 8, the rear surface 48 impacts the forward

surface 47 and provides a second higher modulus of elasticity for the ball striking wall 12 and prevents failure of the ball striking wall.

The face wall 12 is preferably constructed of a forged beta titanium material with a very thin thickness, on the order of 0.030 to 0.100 inches.

While not shown clearly in the drawings, a shoulder is provided at 49 in Fig. 8 on perimeter wall 50 to locate the face wall 12 in the body prior to welding. Both the reinforcing wall 42 and the face wall 12 are welded in the body 11.

An important aspect of the present invention is that the reinforcing wall 42 is extremely light and relatively thin. These attributes are effected because the wall is open cellular in construction. That is, the cell portions 53 and 54 for example, shown in Fig. 5 as well as the others illustrated there, are open. Moreover, wall 42 is constructed of a light-weight material such as titanium and could in fact be constructed of beta titanium because it may be a forged member.

The wall 42 is constructed of a plurality of horizontal bars 56a, 56b, 56c, 56d, and 56e, intersected by a plurality of vertical bars 57a through 57g, surrounded by a narrow perimeter wall 60 illustrated in Fig. 3.

It should be understood that the drawings, and particularly Figs. 1, 2, 4, 5, 6, 7 and 8, are drawn to scale in the original patent application drawings and may be measured for specific values that may or may not be contained in the specification or claims in this application. The cells 53 and 54 have horizontal and vertical values of approximately 0.480 x 0.480.

Each of the bars 56 and 57 are T-shaped in cross section, as seen in Fig. 8, having a flange portion 60 and a web portion 61 projecting forwardly toward the ball striking wall 12a. Thus, each of the bars defines a "T" beam where the maximum stress is at the rear surface of the flange 60, which is the widest and strongest part of the bar. The rear surface of the flange 60, of course, goes into tension upon ball impact while the forward surface of the web 61 goes into compression at ball impact according to known beam technology.

The flanges 60 have a width of approximately 0.100 inches, and a height in a horizontal direction of approximately 0.060 inches while the web 61 has a width in a vertical direction approximately 0.060 inches and a height in a horizontal direction of approximately 0.060 inches. These are only approximate values and could vary sig-

nificantly after a period of testing. The cross section of the bars 56 and 57 provide a maximum strength to weight ratio because of the T-shaped configuration.

Furthermore, it should be understood according to the present invention that the reinforcing wall 42 could be cast with all or part of the body 11. Core pieces can easily be pulled forwardly from wall 42 because the bars 56 and 57 have no side draft to prevent core piece removal.

The gap 65 between the wall 42 and the rear of the film 40 is determined by the experimentation and testing described below in connection with the Figs. 9 to 40 embodiments and in the above Summary.

Referring now to the subject matter of parent application, U.S. Serial No. 09/614,107, Filed: 7-12-00, and U.S. Serial No. 09/344,172, Filed: 6-24-99, and initially to Figs. 9 to 24, a club head 110 is illustrated according to the present invention that includes a standard body 111 and interchangeable face walls 112. The body 111 may be formed in forward and rear pieces as described in my U.S. Patent No. 5,888,148.

The body 111 includes an upper crown wall 113, a toe wall 114, a heel wall 115, and a sole plate 117. An external portion 119 of the hosel assembly 120 shown in Fig. 12, projects upwardly from the crown wall 111.

The hosel assembly 120 includes an upper portion 121 and a spaced lower portion 122.

The crown wall 113, the toe wall 114, the heel wall 115, and the sole plate 117 together form the perimeter wall that surrounds the ball striking face wall 112.

As seen in Figs. 5 and 11, a secondary wall 126 is positioned rearwardly behind the face wall 112a and is positioned to be impacted when the club head strikes the golf ball with sufficient club head speed as shown in Fig. 14.

The secondary wall 126 has a unit cellular structure 128 cast integrally therewith that supports and rigidifies the secondary wall 126 reducing secondary wall weight. It should be understood that the secondary wall and the unit cellular structure 128, which takes the form of a honeycombing pattern shown in Fig. 12, are cast integrally with the club head body 111, or if the club head body is formed with forward and rear pieces along a parting line generally along the section line 4-4 of Fig. 11, the secondary wall 126 would be cast with the forward portion of the club head body.

An important aspect of the present invention is that the club head body is identical for all clubs in the line, and only the face walls shown in Figs. 15 to 18 change from one club in the line to another.

As seen in Fig. 24, the club head body has a recess 130 that extends entirely around the face wall 112 and receives a flange 132 on the face wall that extends completely around the face wall. The recess 130 includes a mounting surface 133 and a shoulder 134.

Viewing Figs. 15 to 18, it can be seen that there are four face walls depicted in this portion of the specification. Namely, Fig. 15 illustrates the 50 to 65 mph club face; Fig. 16 depicts the 66 to 80 mph club face; Fig. 17, the 81 to 95 mph club face; and Fig. 18, the 96 to 105 mph club face, and the completed club head assemblies corresponding to these four faces are shown in Figs. 20, 22, 23, and 24 respectively.

Viewing Figs. 15 to 18, where value 138 represents face thickness and value 39 represents secondary wall spacing, as they do also in Figs. 16, 17, and 18, as well as Figs. 20, 22, 23 and 24. The configuration of the flanges 132 permits the use of a standardized club head body 111 and the automatic determination of the secondary wall spacing 139. This is achieved by progressively decreasing the height of the lower mounting surface 141 of the flange 141 as the face thickens in the face walls 112a, 112b, 112c, and 112d. In fact, in the 112d face wall, the mounting surface 41 is recessed above the rear wall 142 of the face wall.

Viewing Fig. 20, which is an assembly of face wall 112a into the standard body 111, the total forward club surface includes a perimeter wall portion 144 on the club head body adjacent shoulder 34. Wall 144 is designed so it is flush with the forward surface 145 of the face wall 112a and requires substantially only weld grinding after the face wall is welded into the recess 130.

Face wall 112b illustrated in Fig. 22, because of the flange 141 projection shown in Fig. 16, positions the forward surface 146 of the face wall below surface 144 so that after welding, surface 144 must be ground down flush with surface 146.

Similarly, the forward surfaces of the face walls 112c and 112d illustrated in Figs. 23 and 24, require progressively more grinding of surface or wall 144 after welding.

As can be seen, this enables the use of a standardized body and the automatic simple achievement of accurate secondary wall-face wall spacing during assembly.

The club head 210 illustrated in Figs. 25 to 34 is preferably constructed of a titanium alloy such as 6AV4, which signifies a high titanium alloy of 6% aluminum, 4% vanadium, and the balance pure titanium. The club head 210 has a volume of 280 cm.^{3}, and ball striking face area of 43.25 cm.^{3}. Aspects of the present invention are applicable

to "wood" type club heads having total volumes in the range of 150 to over 300 cm.^{3}, as well as face areas in the range of 25 to over 45 cm.^{3}.

The club head 210 illustrated in Figs. 25 to 31 is the subject of parent application, U.S. Serial No. 09/344,172, and is constructed of three pieces that are joined together in assembly; namely, a club head forward portion 211 illustrated in Fig. 33, a club head rear portion 212, and a power shaft 213 shown in Figs. 35 and 39. The power shaft 213 is cast or formed separately from the rear portion, attached to the rear portion by welding or press-fitting it therein.

Viewing Figs. 25 to 34, the club head 210 is seen to generally include a grooved ball striking face wall 215 having an area of about 43.25 cm.^{3} and a wall thickness as viewed in the plane of Figs. 25 to 38 that progressively decreases in the club line from Fig. 35 to Fig. 38. In this regard, the wall thicknesses throughout the club head 210 are in the range of 2 to 3 mm. except for the face wall 215, which varies in the line. A crowned top wall 217 extends integrally and rearwardly from the upper portion of the face wall 215, and it has a short integral hosel segment 218 projecting upwardly therefrom with a shaft receiving bore 219 therein that extends through spaced hosel segments 220 and 221 illustrated in Fig. 33.

A heel wall 223 is integral with and extends in an arcuate path rearwardly from the right side of the face wall 215 as viewed in Fig. 25. A toe wall 224 is formed integrally with the face wall 215 and extends rearwardly in an arcuate path from the extreme toe end of the face wall 215 and is also integrally formed with the top wall 217, as is the heel wall 223.

As seen in Figs. 25 and 26, there is a cavity 226 formed in the bottom of the club head 210 that conforms to the shape of the rear of the power shaft 213. Cavity 226 is defined by a sole plate 227 that is not a separate piece but formed by the forward and rear portions of the club head sub-assemblies illustrated in Figs. 33 and 34. Sole plate 227 has a toe rail 229 and a heel rail 230(see Figs. 25, 26, and 31(that are coplanar as seen when comparing Figs. 29 and 30 and provide the set-up geometry for the club head; i.e., face angle(open-closed), face loft, club head lie, etc. The forward sole plate portion 232 is recessed upwardly from the plane of the set-up rails 229 and 230 and is arcuate when viewed from the bottom of the club head. Sole plate portion 232 connects with an integral upwardly extending semi-spheroidal wall 233 that defines the cavity 226 and extends upwardly from the arcuate rear ends 234 and 235(Fig. 30) of the set-up rails 230 and 229 respectively.

As seen in Fig. 32, semi-spheroidal wall 233 is formed entirely in club head rear sub-assembly 212.

The heel wall 223 and the toe wall 224 smoothly connect tangentially with a club head rear wall 237 that has a semi-ellipsoidal segment 238 welded to and enclosing the rear end of the power shaft 213.

As seen in Fig. 35, the upper semi-annular portion 239 of the spheroidal cavity wall 233 runs along a line parallel to the power shaft 213 and is welded to the sides of the power shaft 213 to increase the modulus of elasticity of the power shaft in the columnar or axial direction.

As seen in Figs. 28 and 28, the club head 210 has a somewhat pointed heel 241 that projects outwardly from the hosel 218 in a direction perpendicular to the axis of the hosel a distance of 15.8 mm. This dimension is taken from the furthest extent of the heel when viewed in the plane of Fig. 27, which is somewhat further from hosel axis 242 than the furthest extent 143 of the face wall 215 because of the radius 244 of the heel wall 223 as seen in Fig. 28. This relationship conforms with the Rules of the USGA.

Viewing Fig. 27, the total heel to toe length of the club head 210, dimension B, is 110 mm., while the total heel to toe length of face wall 115(C+D) in a horizontal direction is somewhat less, about 105 mm. The furthest toe extension on the face wall from a vertical plane containing

geometric center 246, dimension C in Fig. 27, is 48 mm., while the furthest extent of the face wall from the heel to the vertical plane of point 246, dimension D, is 57 mm. Maximum face wall height, dimension E, is 48 mm. and geometric point 246 is spaced a distance of 25 mm.(F) from the ground.

Viewing Fig. 29, total club head length from the lower leading edge of the club face, dimension G, is 90 mm., while the rear end of the top wall 217, dimension H, is 124 mm. off the ground, and the lower rear end of the power tube 213 is 9.5 mm. off the ground(J in Fig. 24).

Viewing Fig. 31, the forward-most portion of the cavity portion 239, from the lower leading edge of the face wall 215(dimension K) is 36 mm., while the rear end of the set-up rails 229 are spaced a distance L from the lower leading edge of the face wall of 54 mm., and the forward portion of the sole plate portion 232 is spaced 22 mm. from the face wall leading edge identified by the letter M in Fig. 31.

Viewing Fig. 33, upper hosel segment 220 has an axial length N of 14 mm., while lower hosel segment 221 has an axial extent P of 12 mm. Distance Q is the horizontal distance from geometric center 246 to the furthest toe extent of the rear portion casting 217, and that value is 50 mm.

The power shaft 213 has an outer diameter of 13 mm. and a wall thickness of 0.8 mm., although shown somewhat heavier in the drawings.

Viewing Fig. 33, face wall 215 has integral reinforcing ribs 252, 253, 254, 255, 256, 257, and 258 extending outwardly from and integral with an annular socket 248. Ribs 252 and 255 extend generally horizontally while ribs 253 and 257 extend generally vertically. Rib 252 connects with and is integral with rib 258 that is integral with and approximately midway up the heel wall 223. As seen in Fig. 32, rib 258 extends all the way to the rear end of the heel wall 223. Rib 253 connects with and is integral with top wall rib 259 that extends centrally in the top wall 217 and rearwardly to the rear end of the top of the power shaft 213 as seen in Fig. 34.

Face wall rib 255 connects with and is integral with toe wall rib 261 that extends rearwardly and generally centrally in the toe wall 224 to the rear end of the club head, as seen in Fig. 34. The top wall has additional ribs 262 and 263 that also extend to the rear end of the top wall 217.

Connecting ribs 262, 263, 264, 265 and 266 interconnect ribs 252 to 257, 257 to 256, 256 to 255, 255 to 254, and 254 to 253 respectively to provide additional reinforcement for face wall 215.

All of these ribs have a width slightly over 3 mm. and a thickness(their extension from the inner surface of the walls from which they project) of about 2 mm.

As seen in Fig. 32, the parting line between the forward portion 211 and the rear portion 212, which are separate castings, is about 21.5 mm. from the lower leading edge of the face wall 215 in a rearward direction along a vertical plane extending along the target line through point 246.

A socket similar to socket 248 can be provided in the rear of the club head to receive the rear end of the power shaft 213 to eliminate welding the power shaft 213 to the rear end of the club. However, minor heat distortion caused by welding the rear end of the club to the rear wall of the club is not a significant problem.

Viewing Figs. 35, 36, 37 and 38, the four clubs in the present line of clubs are depicted with the highest swing speed club depicted in Fig. 35, and the lowest swing speed club depicted in Fig. 38. As may be seen in these Figures, the face wall 215a in the club head 210a seen in Fig. 35 has the heaviest face wall, and hence, the highest face wall modulus of elasticity, the face walls 215b, 215c, and 215d are progressively thinner with wall 215d having the lowest face wall modulus of elasticity. It should be understood, however, that any number of clubs may constitute a

club line according to the present invention, and in fact, in the Fig. 40 Stress Strain Curves, five club heads are illustrated rather than the four shown in Figs. 35 to 38. Ideally, there should be a greater number of clubs in the line to tailor the line to more golfers. If each club head was designed for a 5 mph swing speed range, there could be 15 or more clubs in the line. However, the number of clubs in the line should really not exceed about eight to minimize customer confusion when selecting the swing speed club for his or her range. For explanation purposes only, the club head 210d in Fig. 38 is assumed to be the 50 to 65 mph club head illustrated in Fig. 40; the club head 210c illustrated in Fig. 37 will be assumed to be the 66 to 80 mph illustrated in Fig. 32; the club head 110b depicted in Fig. 36 will be assumed to be the 81 to 95 mph club head in Fig. 40; and the club head 210a depicted in Fig. 35 will be assumed to be the 96 to 105 mph club head in Fig. 40.

The power tube assembly 213 includes an annular tube, welded to an annular socket 271 formed integrally in the rear of the club head, the closure cap 238, the socket 248, and piston 273 welded to the front end of the tube 270 and slidable in socket bore 275.

The piston 273 has a downwardly stepped rear portion 277 that fits inside tube 270, an annular through bore 278, and a central annular groove 279 that receives a rubber

"O" ring 281. The outer diameter of the "O" ring 280 is larger than the outer diameter of the piston 273 to minimize lateral vibration of the piston 273 against the walls of socket bore 283 and reduce the noise level at ball impact. Hole 278 is necessary so that no air is compressed between the forward face of the piston and the socket 275.

The spacing of the piston forward wall 284 from the socket bottom wall 285 is an important aspect of the present invention and is not necessarily, but may be, the same in each of the club heads 210a, 210b, 210c, and 210d. In all of the club heads in the line, however, the swing speed at which the rear of the face wall 215 impacts the forward surface of the piston 284 have a specific relation to the swing speed range for which that club head is designed. For example, the low swing speed range club head 210d; i.e., 50 to 65 mph, might be designed to have a piston impact at 65 mph. It could, however, be somewhat higher or somewhat lower than 65 mph, and the exact impact speed point should best be determined by club head testing. In any event, whatever the relation of piston impact speed to the club head speed range should be consistent with all of the clubs 210a, 210b, 210c, and 210d in the line.

As noted above, the spacing between the forward face 284 of the piston and the bottom wall 285 of the cavity, is shown approximately the same in club head 210a,

210b, 210c, and 210d, but in practice the piston spacing or piston clearance may be different in each of the club heads depending upon the modula of elasticity of face walls 215a, 215b, 215c and 215d.

Piston clearance is determined experimentally and is selected so that piston impact occurs at about 85% of the strain at the yield point of the face wall. The yield point, of course, is that point on the Stress Strain Curve whereupon relaxation of the face wall it does not follow the Stress Strain Curve during compression. One method for making this determination is with a variety of face wall thicknesses. For example, ten part 211s could be constructed having face wall thicknesses from .050 inches to 0.150 inches in .010 increments. These part 211s are then placed in a compression machine with a plotting stylus, parting line surface downwardly and face wall 215 upwardly. A semi-hemisphere golf ball is then placed between the upper platen and the club face, arcuate surface against the base, of course, and compression testing is conducted using a dial indicator for measuring face deflection from below on the rear of the face wall. The yield point is quite easily determined in a plotting compression testing machine by cycling up and down the stress strain curve with increasing cycle length until the stylus fails to return exactly down the compression line. The maximum deflection at the yield

point on the dial indicator is then tabulated for each of the club heads, and since these club heads have reached the yield point, they have been damaged and cannot be used for further testing. Then duplicates of these heads are utilized to make assembled club heads with the clearance space of the piston being 85% of the tabulated yield strains noted in the compression testing. This 15% safety factor is desirable because there is a mild amount of stress repetition fracture in golf club heads, even those that are well made.

After the club heads 210a to 210d have been assembled, or however many are being tested, with the appropriate piston clearance for each club head, the club heads are tested utilizing a mechanical club swinging device with accurate club head speed measurement capability. The swing speed range for each head is determined by noting the club head swing speed at which piston impact occurs. Piston impact produces a significant change in ball impact sound and is easily noted by the testing crew. For example, club head 110d was noted to have piston impact at 65 mph swing speed so that swing speed(or something close to that speed) is assigned to club head 210d as the upper limit of its swing speed range. The lower limit for the slowest swing speed in the low swing speed club in the line, of course, is an arbitrary value. Obviously, the golfer that swings near

the upper end of the range is going to benefit most from this club head line design, and that is why ideally there should be more than four clubs in the line.

In Fig. 40, the strain line 286 represents the strain at 85% of the yield point. As noted above, while the strain is shown equal for all the clubs in Fig. 40, they are not necessarily equal, but may be as a consequence of coincidence. Line 286 thus represents the strain at which the piston impacts the bottom of the socket 285 in each of the club heads. In each of these curves, 210a, 210b, 210c, and 210d, the slope of the lower portion of the curve 287 is proportional to the modulus of elasticity of the face wall unsupported by the power piston assembly 213, and the slope of the second portion 289 of the curves represents the modulus of elasticity of the face wall after it impacts the power piston assembly 213 and, of course, in each case is seen to be substantially higher than the slope of portion 287. It should be noted that the slope of the stress strain curves in Fig. 40 is proportional to modulus of elasticity.

As discussed briefly above, the fundamental principles of the present invention can be applied with a lesser benefit to a single club as opposed to a multiple club line. Some manufactures may prefer to utilize these design principles in a single club because they may view the custom clubfitting process as being customer confusing or retailer

confusing because it requires measuring the customer's swing speed, usually with an electronic swing speed measuring device. Most average golfers have swing speeds in the range of 60 to 90 mph. If a club manufacturer preferred to make a one club line, the club could be designed so that face wall impact with the front face of the piston would occur at a 90 mph swing speed. This design, of course, would benefit the 85 to 90 mph swing speed the most, with a lesser benefit for those players in the 60 to 85 mph range. And if a player above 90 mph used the club, he would not damage the club because of the increased modulus of elasticity above 90 mph. This benefit is also characteristic of the multiple club line designs described above when using swing speeds above each of the designed ranges.